U.S. House of Representatives testimony before the Committee on Science, Next Generation Internet Initiative
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Mr. Chairman and Members of the Committee, I am pleased to appear before you today to speak about the Next Generation Internet initiative, a critical element of our efforts to help advance the frontiers of information technology.

Vision for the Information Age

At the beginning of his first term, President Clinton articulated a vision for working with the private sector to develop an advanced information infrastructure for our nation. The core of that vision lay in harnessing the potential benefits to be derived from applications of advanced computing and communications technology. The Internet and the World Wide Web, then still largely the province of military and academic researchers, joined by technology buffs, were held as potential models for how computer networks, telecommunications services, and applications might be interconnected to open up new vistas and profoundly change much of American life.

With the private sector taking the lead, we set out to make the President's vision a reality. But none of us could have predicted the speed with which information systems built around the Internet would move into commercial use, transforming the way we work, where we work, and what we need to know to be successful in today's economy. Today, fast, flexible, and reliable information systems, many of them based on Internet technologies have become essential tools for business, communications, education, health care, and entertainment. More than 30 percent of U.S. investment in new plant and equipment is for information technology. The Internet has made geography irrelevant, allowing individuals, communities, and businesses to access libraries, art collections, medical and scientific information, business contacts, and government documents located throughout the nation and around the world. The Information Age is upon us; it is no longer in the future.

And with the Information Age, we have entered an unprecedented era of global communications and information flow. The speed with which information is created, its accessibility, and its myriad uses are increasingly among the determining factors in a nation's competitiveness in the global economy. We are witnessing the emergence of new paradigms for global trade of goods and services, bringing with it both opportunities and challenges for individuals, industry, and governments throughout the world. As Vice President Gore stated eloquently on July 1, 1997, on the occasion of the

release of the Administration's Global Framework for Electronic Commerce:

"We are on the verge of a revolution that is just as profound as the change in the economy that came with the Industrial Revolution. Soon electronic networks will allow people to transcend the barriers of time and distance and take advantage of global markets and business opportunities not even imaginable today, opening up a new world of economic possibility and progress."

Constraints on the Revolution

Despite the dramatic and global growth of the Internet, we have only just begun to tap into the opportunities -- and to encounter the challenges -- which it presents. Exciting new applications for scientific research, telemedecine, lifelong learning, global electronic commerce and other disciplines remain momentarily out of reach, constrained by the capacity and capabilities of today's Internet technologies, which were not designed for either the scale or mode of its current use. Even though new applications and dramatic private investment have increased the Internet's capabilities, technological bottlenecks have sprung up throughout the system. The first-generation Internet technologies are reaching the limits of their capabilities.

Our national Internet infrastructure is straining to meet demands for increased communication speeds, service quality, and greater bandwidth to deliver information and services to American citizens and businesses. Today, slow end-to-end performance frustrates engineers anxious to collaborate on the design and simulated testing of large projects. Educators have wonderful ideas about using powerful new information tools to transform the lifelong learning process -- making it more accessible, more productive, and more up-to-date -- but much greater communication speeds are needed to bring many of these visions to life. Schools and businesses are bristling with ideas for a system that could move interactive, full motion video through the Internet more cheaply and easily than we now move text. The medical community needs increased communication speeds and data processing capabilities so that specialists around the country can collaborate in the treatment of patients -- even if they are in small rural hospitals.

The Federal government also has increased demands for high-speed communications and advanced applications which impact Federal agencies' abilities to perform their missions. Working with massive data bases such as the NIH Visible Human or the NASA images of Mars can require moving a billion bits of information per second -- an impossible requirement for today's communication systems. Secure, reliable, high-speed information systems are essential for our national security to help manage the battlefields of future conflicts. Today, even the fastest operational DOD systems need six hours to send the kinds of information battlefield commanders would like to have about a 100x100 mile battlefield. Advanced communications systems are essential for the operations of the nation's science and technology research enterprise, linking the technologically sophisticated research facilities of the Department of Energy's national laboratory system with industry and university partners. NSF's support of university research includes the high-speed Connections Program, since advanced communications are as important to most university research as buildings and lab equipment. In fact, in order to assure that connections to high performance networks reach even our most geographically remote research institutions, NSF's Director, Dr.

Neal Lane, recently announced in a letter to Senator Conrad Burns (R.-Montana) that the Connections Program and the Experimental Program to Simulate Competitive Research (EPSCoR) would jointly fund proposals to connect EPSCoR states. I have attached a copy of this letter to my testimony.

Clearly, there is plenty of business for anyone able to provide the right applications efficiently over cheap bandwidth with high-quality end-to-end performance. We expect that much of the innovation and investment needed to improve today's information infrastructure will come from the dynamic and highly competitive companies -- both old and new -- that have expanded to meet this exploding new demand. Yet we have discovered that some of the constraints to the current-generation Internet go beyond a question of insufficient capacity in the face of explosive demand for innovation in services and applications. We are also facing issues of the limits of our understanding of network design, management and operations. The demands of a next generation Internet will require interconnection and management of larger and higher-speed networks, carrying differentiated services and enabling sophisticated applications. Currently, we can only guess at how to accomplish this reliably, securely, and with quality end-to-end performance. Only through fundamental research can we advance to harness the possibilities of increased capacity (speed), improved capabilities (quality of service and security) and revolutionary applications.

Federal Role and The Next Generation Internet (NGI)

With our Next Generation Internet (NGI) initiative, we hope to leverage Federal investment in advanced information technologies to provide exactly this type of long-term fundamental research. Our aim is to work in partnership with the university community and the private sector to undertake fundamental research and to provide opportunities to demonstrate new technologies and applications in support of national goals and key Federal missions.

Federal government investment provided the seed corn to speed the development of today's Internet. Beginning in the late 1960's and continuing into the 1980s, DARPA and NSF invested in research to develop the technologies and networking infrastructure to connect universities and Federal laboratories in an experimental system designed for the specialized needs of academic, research, and military information. From this initial government-sponsored research has come a $200 billion plus market capitalization, new and innovative services and applications, and the transformation of our society. While we cannot accurately assess at this time the full impact of this new phase of Federal investment, we have already glimpsed the promise of revolutionary applications and services to be unleashed by increasing capacity and improving capabilities of networks.

There are several reasons why it is appropriate for the Federal government promote and participate in NGI research. First, the private sector is unlikely to undertake this type of highly collaborative, long-term research and development on its own, especially in longer term research areas that will benefit the economy as a whole as opposed to any one firm. Second, we have an obligation to ensure that the United States continues to lead the world in the development and use of information technologies -- technologies that are key to a robust 21st-century economy. Much of current U.S. leadership in the information and communications industries can be

traced to prior Federal investments made over the past three decades. Third, Federal agencies must have access to state-of-the-art communication and information systems to effectively fulfill their own missions. And finally, Federal research agencies have an obligation to ensure that American universities and researchers are connected with the best possible communication systems.

Experts outside the Federal government agree that there is a need for a Next Generation Internet initiative and that the time to do it is now. Members of our Presidential Advisory Committee on High Performance Computing and Communications, Information Technology, and the Next Generation Internet are appearing before you today to share their endorsement of the NGI goals and our proposed research agenda. This Advisory Committee is comprised of industry and academic leaders in computing and communications from across the nation. Endorsements of the NGI have also come from other business and university leaders from companies such as BBN Systems & Technologies, General Electric, Lucent Technologies, Cisco Systems, and institutions such as the University of Michigan and Pennsylvania State University. Finally, the community of U.S. networking experts, including some members of our Advisory Committee, came together with our Federal experts last May to define the collaborative research that is the core of the NGI. This workshop, sponsored by the industry groups Computer Research Association (CRA), Computer Systems Policy Project (CSPP), and Cross Industry Working Team (XIWT), concluded that the NGI is essential for "using the Internet's promise and ... to accelerate the rate of future networking development." Workshop participants identified areas where government-sponsored initiatives could be helpful to the NGI, which the Federal NGI implementation team used to refine its plan. The workshop proceedings were published by CRA; copies were delivered to the Committee last week by our National Coordination Office for Computing, Information, and Communications.

The Next Generation Internet: Purpose and Goals

So, what exactly is the NGI?

The NGI is an advanced research initiative which fosters partnerships among academia, industry and Federal laboratories to develop and experiment with technologies that will enable more powerful and versatile information networks of the 21st century. The program's overall objective is to perform fundamental research in technologies that will accelerate the development of a high-speed, high-quality network infrastructure to support revolutionary applications. It is not, as some have mistakenly believed, a program to deploy network infrastructure. We will work in close partnership with private firms who will take the risks and make the investments needed to bring NGI research into commercial markets. This is how the Internet itself moved from a DARPA/NSF research project to become an enormous commercial success.

There are three goals for the NGI initiative:

The first goal is Experimental Research for Advanced Technologies. Under this goal, NGI researchers will develop and demonstrate the advanced network service technologies -- that is, the technologies which provide functional capabilities to the network -- needed to support next generation applications. For example, high-quality

team collaboration and network management to handle the routing, quality of service, and security demands for multicasting across thousands of high performance networks handling speeds that are 100 to 1000 times faster than today's Internet require network services that are not available with current technology. These services must be richer in features, higher in performance, and deliverable at reasonable cost. Main areas which will be developed and demonstrated include quality of service, security and robustness, network management, and protocols for collaborative and distributed applications environments.

The second goal is to weave the Next Generation Network Fabric. The NGI will develop a network of NGI sites -- universities, Federal research institutions, and other research partners -- for testing network technologies and new applications. This "network fabric" will be a broadly-based, distributed laboratory, delivering 100+ Mbps (more than 100 times typical current end-to-end capabilities) to at least 100 interconnected NGI sites demonstrating highly important applications. We will be working very closely with the Internet2 consortium to accomplish this goal. Ultra-high connectivity at 1000 times current Internet end-to-end performance (greater than 1 Gbps) will be achieved in smaller wide-area demonstration networks involving about ten NGI sites, and longer term research will be supported for terabit networks.

The third goal is to develop Revolutionary Applications. The NGI will demonstrate new applications that meet important national goals and missions, ideally to include Federal agency mission applications, university and other not-for-profit applications and private sector applications. Potential application areas are likely to be in health care, education, scientific research, national security, environment, government, emergency management and design and manufacturing.

In the Internet world, ideas move quickly. Using the Internet, we published preliminary drafts of our NGI concept paper and implementation plans for public comment last April. Since then, we have benefitted enormously in refining the design of the NGI from comments and suggestions received from many sources, including Members of Congress and their staffs. Our Presidential Advisory Committee, through its NGI subcommittee, was instrumental in reshaping our key goals to better emphasize the NGI as a research and experimentation program, rather than a program to promote connectivity, as some may have concluded from earlier drafts of NGI plans. Other recommendations from the Advisory Committee were to make key investments at the outset, encourage stronger cooperation, and encourage all sectors to invest to realize benefits. NGI Subcommittee Co-Chair Professor Raj Reddy of Carnegie Mellon University, presented its recommendations to the Administration during a briefing for the Congressional Internet Caucus on June 13, 1997, and at its second meeting, held at the NSF on June 24-25, 1997.

As I mentioned earlier, Advisory Committee members also were active participants in an NGI workshop sponsored by the Computer Research Association, Computer Systems Policy Project, and Cross Industry Working Team back in May. The workshop brought together networking experts from industry, academia and government to flesh out the research agenda for the NGI. The success of this collaborative review, critique and definition by the broader community bodes well for the development of NGI partnerships linking the unique capabilities and resources of Federal agencies, private businesses, and universities. We have also worked to strengthen our relationship with

Internet2, a consortium of universities developing advanced network applications and engineering for research over high-performance networks. For example, we plan to use some of the NGI funding to allow Internet2 members and other universities to purchase high-speed connectivity to the NSF's very high speed Backbone Network Service (vBNS). Many of the technologies that the NGI will support , such as all-optical networking, could eventually be adopted by organizations like Internet2.

The Administration's revised draft NGI Implementation Plan, issued on July 31, 1997, shows the fruits of these consultations and collaborative efforts. Recommendations from the Advisory Committee, results of the CRA workshop, and other beneficial suggestions have been incorporated into detailed goals, metrics, milestones, and agency roles which we believe will provide a Federal research agenda which can be leveraged in partnership with industry and academia to advance the next generation of U.S. communications technologies. Copies of the NGI Implementation Plan, the NGI concept paper, and the CRA's summary of workshop results have been delivered to the Committee.

Agency Roles and Program Management

The NGI initiative builds heavily on the large, dynamic research programs already underway under the coordination of the Committee on Computing, Information and Communications (CCIC) of the National Science and Technology Council. These programs are an outgrowth of the highly successful, Congressionally-chartered High Performance Computing and Communications (HPCC) initiative that was responsible for catapulting the United States into the era of teraop computers, gigabyte networks, and computation-intensive science and engineering applications. Communications research in advanced networking technologies and services, including the NGI, is coordinated by the Large Scale Networking (LSN) working group of the CCIC's Computing, Information and Communications R&D Subcommittee.

Each agency supports components of the CCIC research program that directly support its specific mission, and participates in the interagency process in ways that both advance their own missions and the mission of the combined Federal program. The NGI is no exception. Each participating NGI agency brings specific skills, expertise, and/or applications needs to the project. For example:

- **DARPA:** long-term, general expertise in networking research, general skill in high-end network technology and testbeds, experience in managing networks.
- **DOE:** long-term experience in managing production and research networks, specialized skills in networking technology, great strength in mission-driven applications and in system integration.
- **NASA:** experience in network management and in specialized network testbeds, strength in mission-driven applications involving high data rates, great strength in system engineering and integration.

- **NSF:** special relationships with the academic community, experience in network research and in managing networks, great strength in scientific applications.

- **NIST:** long experience in standards development, networking research, metrology, computer systems security, systems integration for manufacturing applications, and in testbeds involving many industrial partners.

- **National Library of Medicine (NLM)/National Institute of Health (NIH):** extensive experience in medical research; great expertise in health care applications.

The success of the NGI research agenda requires the participation of each of these agencies. Lack of funding would have impacts not only on the ability to achieve Federal NGI technical goals, but also on the technical goals of university and industry collaborators, and on the ability to move advanced technologies rapidly into the commercial sector. For example, insufficient funding to DOE, DARPA, NSF, or NASA would delay advanced interconnections among experimental Federal high-performance networks, which would subsequently degrade access by universities, including Internet2 participants, to Federal laboratories and experimental research facilities. NSF's vBNS and Connections program would not be able to meet the aggressive NGI goals of performance and timing without NGI funding, and so would result in fewer universities being connected to the experimental program. DOE's major contribution to the development and operation of joint industry-national laboratory fiber optic testbed would be discontinued if it is not funded under NGI, which will delay introduction of these technologies into the commercial sector. No NGI funding would limit NIST's ability to bring in critical industry partnerships for experimentation with next generation manufacturing technologies. NLM goals for advancing telemedecine applications -- for example, they hope to reduce the speed of remote transmission of high-quality mammography images from 3 days to 15 minutes -- will not be met in the near future without NGI networking research in the other agencies. My colleagues from the participating Federal R&D agencies can provide you with further details on how limiting their contributions might affect our ability to provide this very critical advanced research for our nation.

Concerns about the management of the NGI have been raised from time to time, and I'd like to assure you that we have a team that has worked well together in the past five years and is ready to work for the future. The strategy for successfully managing the NGI research initiative, as with other CIC interagency research programs, is based on (1) cooperation and coordination among participating agencies, (2) a close relationship between the technology efforts within the NGI initiative and the large applications-level efforts of the agencies, and (3) leveraging existing execution mechanisms within the agencies. A senior interagency team comprised of key officials from Federal R&D agencies provides policy guidance for the entire CCIC enterprise and coordination across the research program areas, including the NGI. The CCIC's Large Scale Networking working group is responsible for NGI implementation strategy. Overall interagency coordination and support are provided by the National Coordination Office for Computing, Information, and Communications. This system of operation has worked well over the past five years. It has earned the respect of all the participating agencies by allowing each agency to speed the achievement of their own mission objectives by working closely with research organizations in other parts of the

government. This team has a demonstrated track record of accomplishment that should enable it to succeed in the future.

We are also working hard to ensure that management of all our Federal R&D programs for CIC, including the NGI, are reviewed by experts from outside the Federal government. I previously mentioned the thorough review given the NGI by our newly appointed Advisory Committee and the networking experts who attended the CRA workshop. The Advisory Committee will be providing us with advice and recommendations on future directions for our Federal investments in high-performance computing and communications and information technology. Twenty-one members have been appointed to the Advisory Committee thus far and we will be naming several new members in the near future. We are committed to ensuring that this advisory panel of the nation's leading experts in these areas represents the long term interests of business, communications, computation, universities, libraries, and information technology from all regions of the United States.

Conclusion

Mr. Chairman and Members of the Committee, I hope this brief overview has conveyed to you the Administration's commitment to ensuring that the U.S. continues to reap the benefits of the Information Age well into the 21st century.

Investments are needed now to stimulate progress in advanced communications and to further U.S. scientific and commercial leadership. Today's Internet is already being challenged by ever-increasing demand for high bandwidth access and multimedia applications. The solutions to these challenges are beyond the scope of any one institution, company, or industry -- and indeed in some cases, beyond the scope of our current technical knowledge. But through the type of collaborative research proposed through our NGI initiative, researchers from industry, academia and government can develop the technologies which will sustain U.S. leadership in information technology.

The NGI, with its broad agenda and ability to involve government, research institutions, and the business sector is a program whose time has come.

I ask that you support the NGI initiative through the authorization of the President's request of $105 million for the program, to be allocated among the participating agencies as set forth in the implementation plan and the concept paper.

Technological leadership as embodied in the NGI will be vital to the national interests of the United States. As we enter the twenty-first century, our ability to harness the power and promise of leading-edge advances in technology will determine, in large measure, our national prosperity, security, and global influence, and with these the standard of living and quality of life of the American people.